Rain Estimates by Using Ku- and Ka-Band Dual-Frequency Radar

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Introduction

An important goal of the Dual-frequency Precipitation Radar (DPR), aboard the Global Precipitation Measurement (GPM) core satellite, is to derive rain rate by estimating parameters of the rain drop size distribution (DSD) that is often modeled by an analytical function, such as the gamma with two or three unknown parameters. The inability of the modeled DSD to represent actual hydrometeor spectra and to characterize their intrinsic variations in time and space lead to errors in the estimates of precipitation rate obtained from the DPR. Understanding the uncertainties in rain rate estimation that depends on DSD parameterizations is important not only in evaluating the overall performance of DPR retrieval algorithms but also in gaining insight into ways to improve the algorithms.

We will investigate performance of dual-wavelength radar techniques in rain estimates with various assumed DSD models by comparing the radar and hydrometeor parameters obtained from the DSD models with those directly derived from DSD measurements. The relations between the radar parameters and hydrometeor properties are the fundamental components of the radar retrieval in the sense that these relationships serve as retrieval look-up tables (LUT). The LUT is DSD-model dependent. The degree to which the results of the LUT agree with the same quantities derived from measured DSD offer a direct check of the radar retrievals.

In this study, the measured DSD data acquired from a variety of storm systems during several NASA-sponsored field campaigns will be used to create radar reflectivity factors at the Ku- and Ka-band frequencies at which the DPR operates, along with hydrometeor bulk and characteristic size parameters. The DSD data that will be used include the multiple Parsivel^2 and 2DVD observations operated during Iowa Flooding Studies (IFloodS), the Midlatitude Continental Convective Clouds Experiment (MC3E) and data from NASA Wallops Flight Facility in Wallops Island, Virginia as well as Olympic Mountains Ground Validation Experiment (OLYMPEX) field campaign.

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Example of DSD

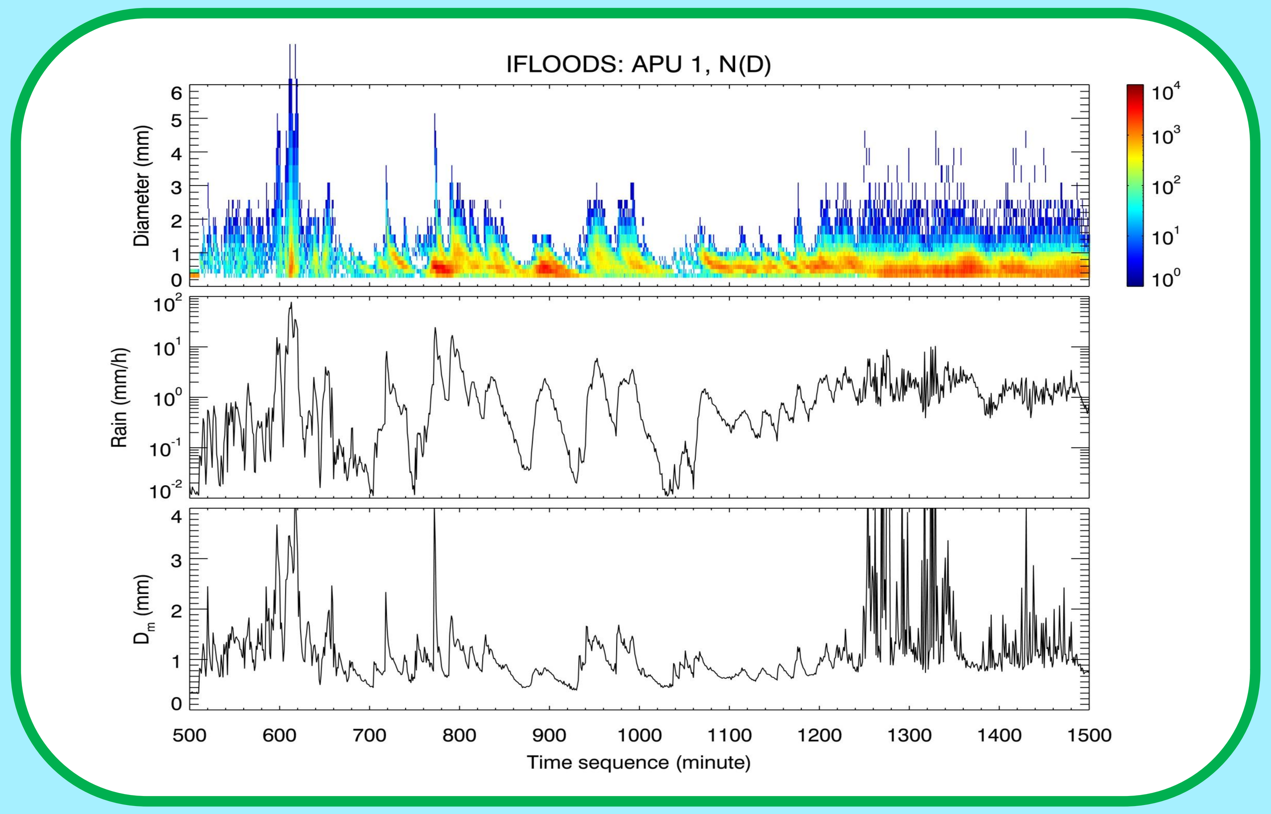

Fig.1 Examples of DSD measurements in time series from the Parsivel disdrometer-1. The image of size spectra (mm^{-1}m^{-3}) and their corresponding rain rate (mm/h) and mass-weighted mean diameter D_m (mm) are respectively shown in top, middle and bottom panels.

Retrieval LUT

The retrieval look-up tables (LUT) are formed in such as way that the radar measurements are directly linked to the micropgysical properties of hydrometeor and its associated bulk parameters.

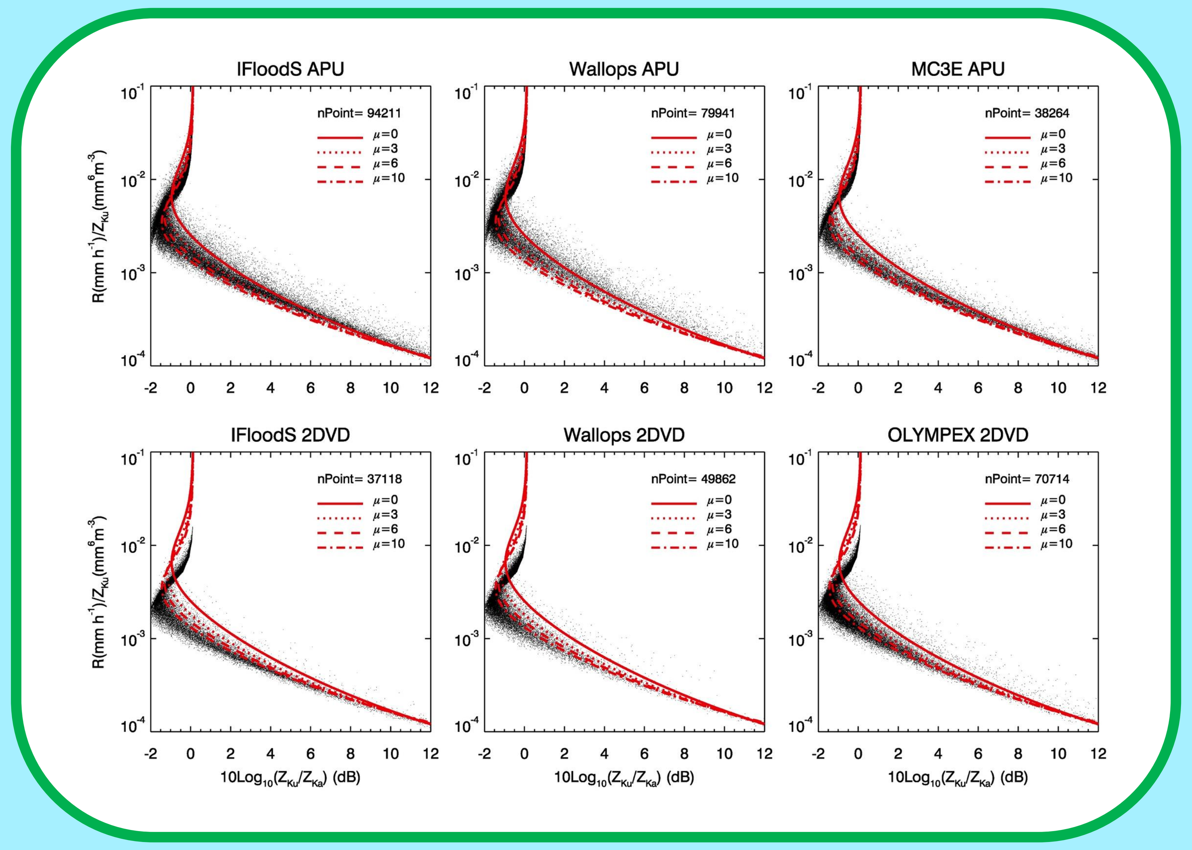

Fig.2 Rain rate (R), which is normalized by the Ku-band radar reflectivity factor (Z_{Ku}), as a function of the DFR, defined by 10LOG$_{10}$(Z_{Ku}/Z_{Ka}), for several shape factors (μ) ranging from 0 to 10 of gamma DSD model. The scatter plots (red dots) are the results derived from the measured DSD that were collected by the Parsivel (APU) and 2DVD disdrometers during several NASA-sponsored field campaigns.

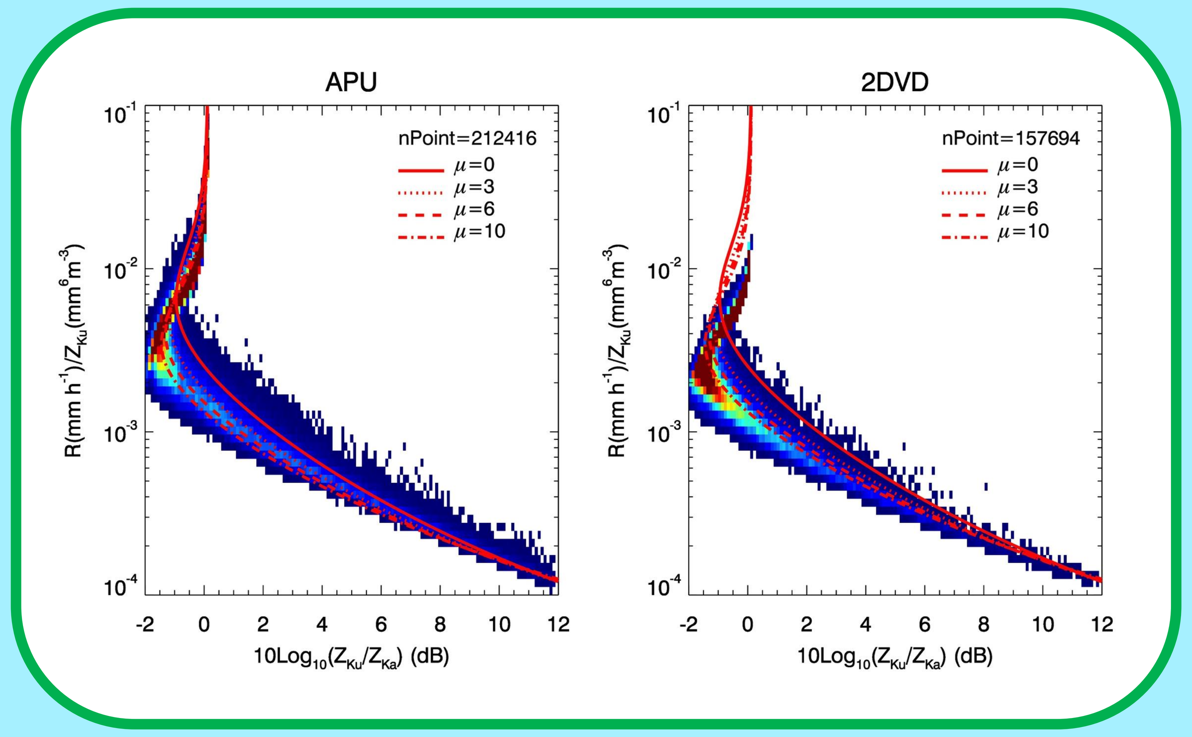

Fig.3 Rain rate (R), which is normalized by the Ku-band radar reflectivity factor (Z_{Ku}), as a function of the DFR, defined by 10LOG$_{10}$(Z_{Ku}/Z_{Ka}), for several gamma DSD models. Two-dimensional PDFs are provided based on all the DSD data from the APU (left) and 2DVD (right).

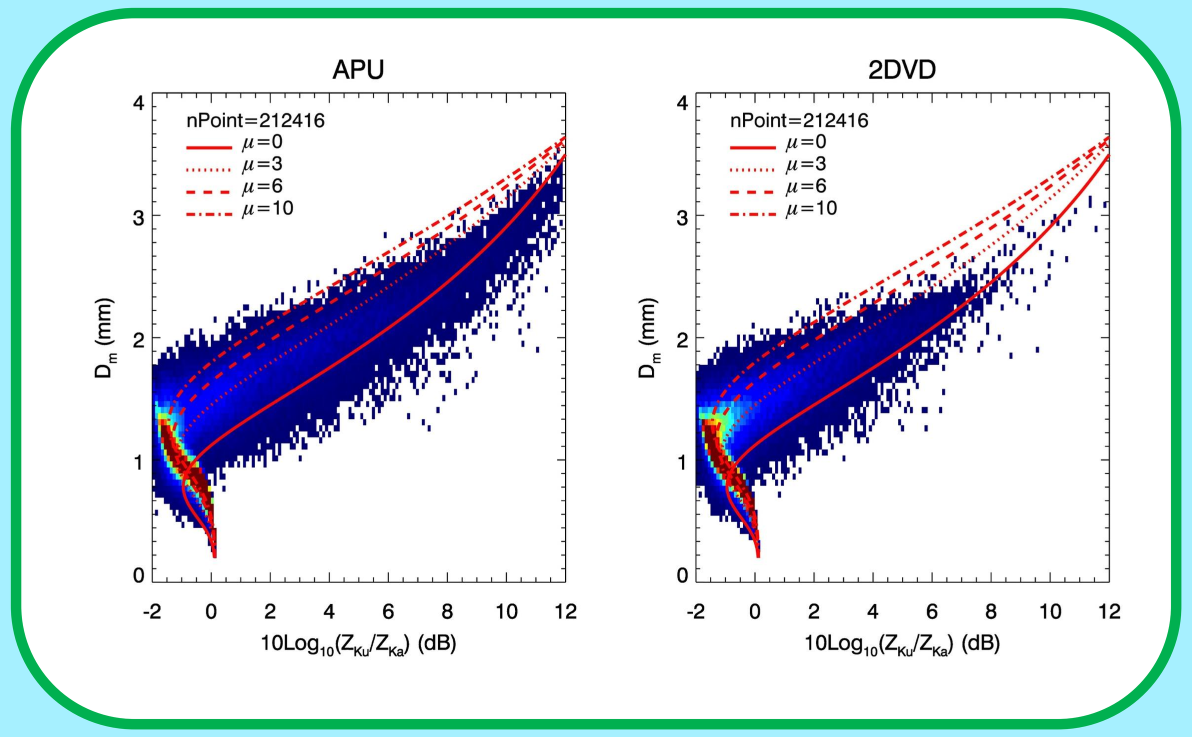

Fig.4 D_m as a function of the DFR, defined by 10LOG$_{10}$(Z_{Ku}/Z_{Ka}), for several gamma DSD models. Two-dimensional PDFs are provided based on all the DSD data from the APU (left) and 2DVD (right).

Relative Errors

1. Fixed-μ DSD model

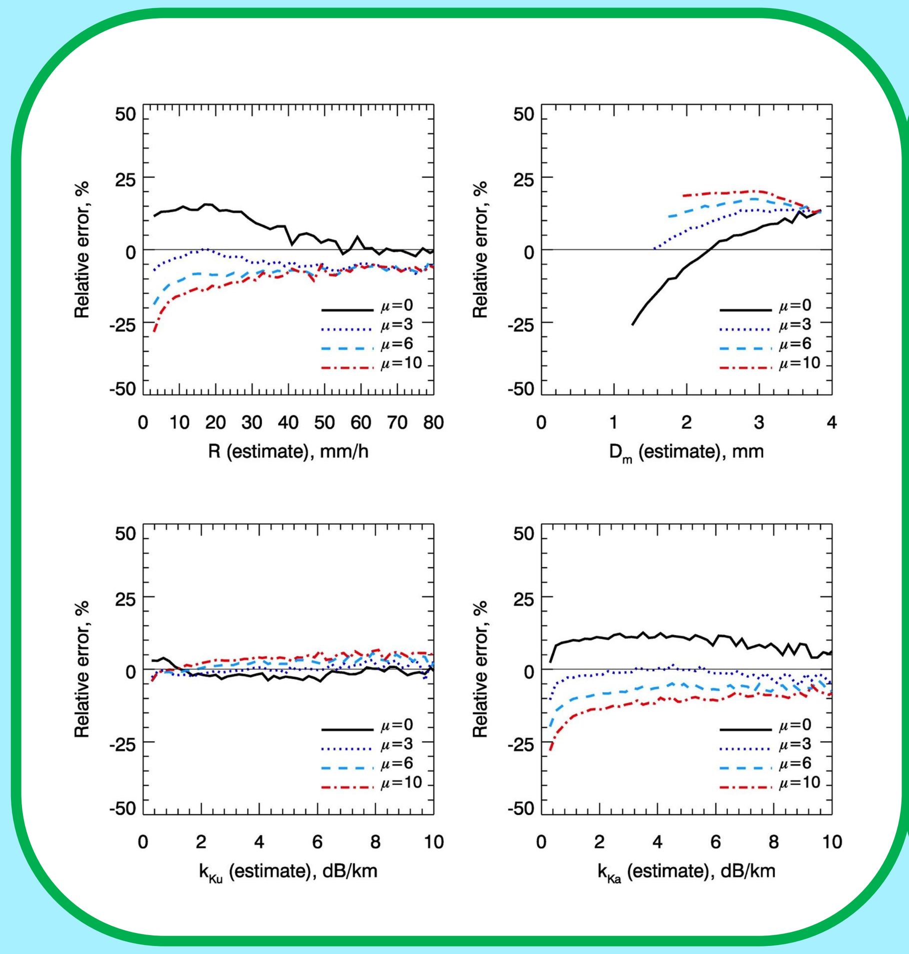

Fig.5 Mean of relative error of retrieved rain rate, D_m and Ku- and Ka-band specific attenuations (k_{Ku} and k_{Ka}) as compared with their true values derived from DSD data that are collected from Parsivel disdrometers during IFloodS, Wallops Island and MC3E when the DSD model for the retrieval is assumed as a fixed-μ gamma distribution.

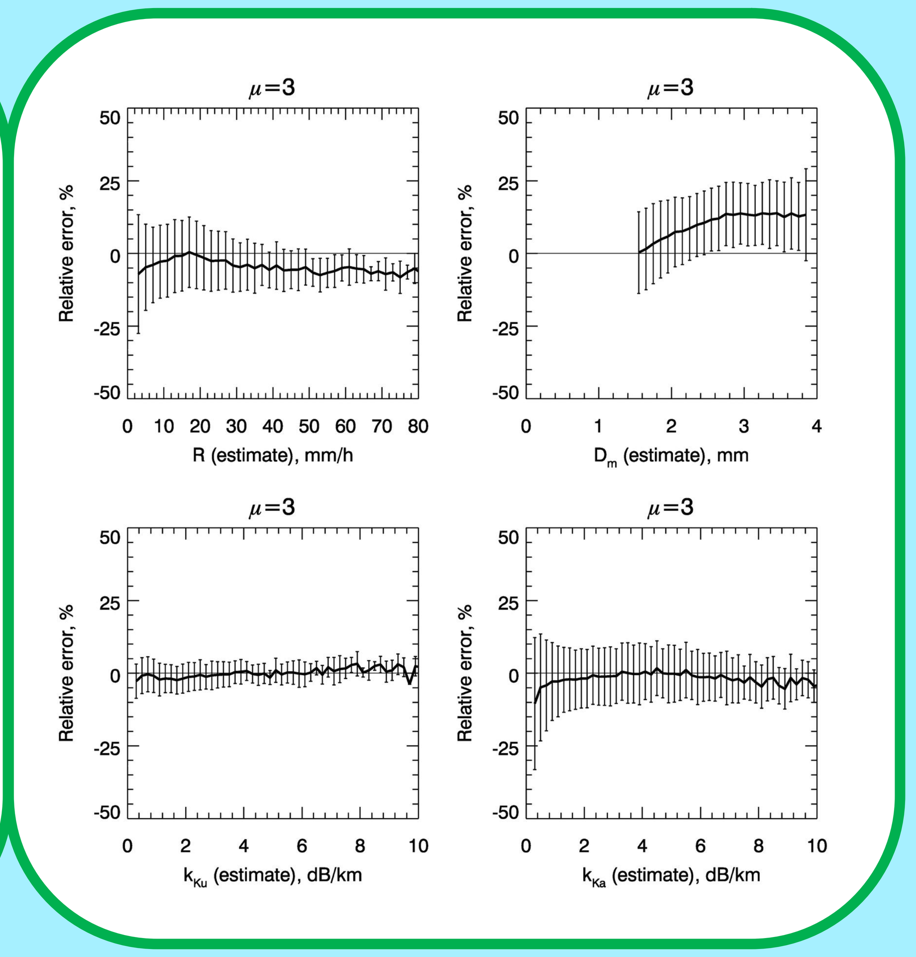

Fig.6 Mean and standard deviation of relative error of retrieved rain rate, D_m and Ku- and Ka-band specific attenuations (k_{Ku} and k_{Ka}) as compared with their true values derived from DSD data that are collected from Parsivel disdrometers during IFloodS, Wallops Island and MC3E when μ of the assumed gamma distribution is set to 3.

2. μ-Λ DSD model

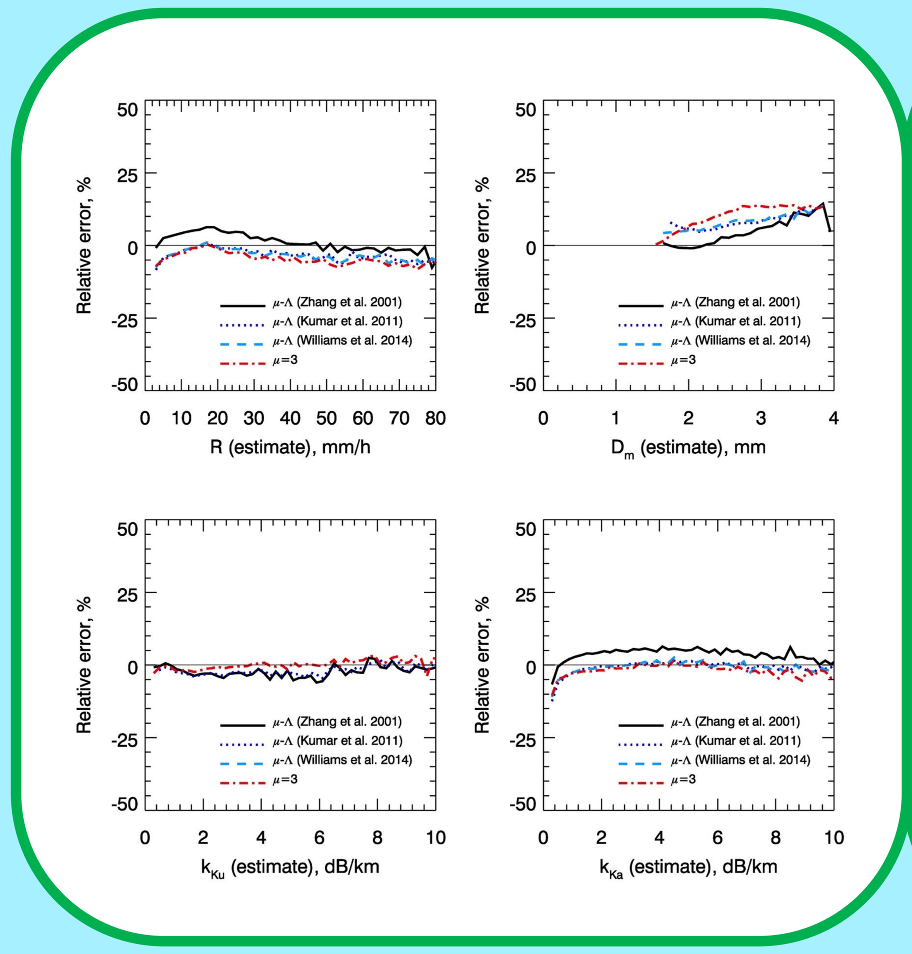

Fig.8 Mean of relative error of retrieved rain rate, D_m and Ku- and Ka-band specific attenuations (k_{Ku} and k_{Ka}) as compared with their true values derived from DSD data that are collected from Parsivel disdrometers during IFloodS, Wallops Island and MC3E when the DSD model for the retrieval is assumed as a μ-Λ gamma distribution.

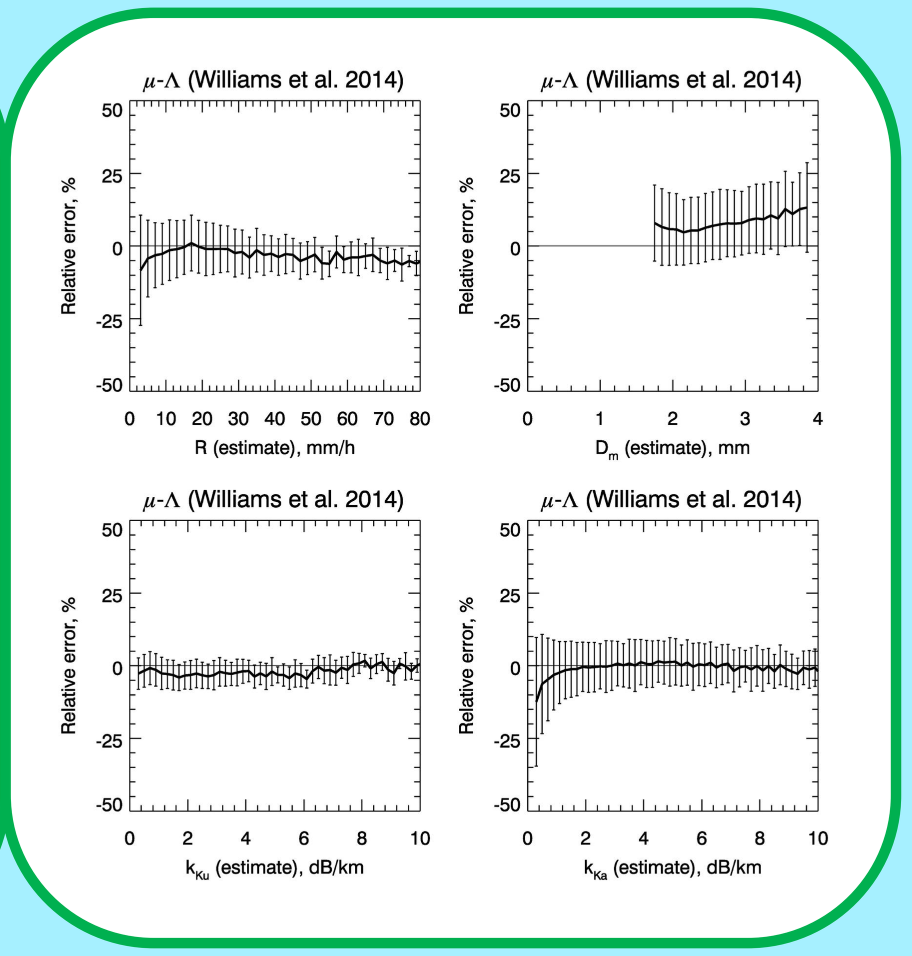

Fig.8 Mean and standard deviation of relative error of retrieved rain rate, D_m and Ku- and Ka-band specific attenuations (k_{Ku} and k_{Ka}) as compared with their true values derived from DSD data that are collected from Parsivel disdrometers during IFloodS, Wallops Island and MC3E when the μ-Λ relation reported by Williams et al. 2014 is used.

Remarks

- Uncertainties in DSD models employed in the Ku- and Ka-band dual-λ technique have been assessed.
- Impact of DSD parameterizations, such as gamma distribution (fixed-μ & μ-Λ) on rain estimation has been examined using measured DSD data collected from various sites and field campaigns.
- A μ=3 gamma DSD works as nearly well as μ-Λ DSD models in estimates of rain and attenuations.